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METHOD AND SYSTEM FOR LOW-DOSE THREE-DIMENSIONAL IMAGING OF A SCENE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Patent Application No. 60/181,981 filed on February 11, 2000.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was made with government support under Contract No. CA66232 awarded by the National Cancer Institute. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

The present invention relates generally to methods and systems for imaging a scene using a low dose of radiation and more specifically to method and system for generating a three-dimensional image of a body part using a low dose of x-ray radiation.

Systems that utilize high energy radiation, such as x-radiation and gamma radiation, to examine the internal structure of a solid object are known. Such systems typically irradiate an object under examination with high energy x-radiation or gamma radiation and utilize detection apparatus to measure the intensity of the radiation that is transmitted through the object.

It is known that these systems may be used to produce images of body parts. Detection systems, particularly those used for medical applications, such as mammography, direct x-rays through the body part of interest toward an x-ray detector. The x-ray detector receives x-rays transmitted through the body part and produces an image of the body part based on the intensity distribution of the x-rays incident on the detector.

In conventional x-ray mammography systems, two images of the breast are made. Each of the images are obtained at approximately right angles to each other. The purpose of obtaining images at two different angles is to increase the likelihood of seeing features in the breast that are not recognizable from one direction, but which may be discernable in another direction.

Conventional mammagraphy techniques, however, have significant false negative and false positive rates that can result in either missing cancers in their early stages or in

unnecessary surgical procedures. False results are due, in part, to the limitations of projecting a three-dimensional object into a two-dimensional image.
In particular, structures at one level in the breast may partially or entirely obscure structures at another level, making identification of cancers difficult. In addition, the superimposition of normal structures at different levels may create an image that erroneously looks like a cancer. The overlapping of structures prevents visualization of a true representation of the breast and is referred to herein as structure noise. In addition, breast imaging using only two transmission images of a breast suffers from low contrast differences between normal and cancerous tissues.

One method for reducing structure noise is to perform a three-dimensional reconstruction of the breast using three-dimensional x-ray imaging, known as computed tomography (hereinafter "CT"). In conventional CT imaging, hundreds or thousands of x-ray images are recorded. These images are analyzed using computational methods to generate a three-dimensional image of the breast. The radiologist may separate the three-dimensional image into slices in order to separate the images of overlapping structures and better analyze the image. However, the number of images needed for conventional CT requires too high a dose of radiation to be used routinely on patients. High doses of radiation are required to obtain high-resolution three-dimensional images. CT techniques have not been applied to screening for breast cancer due to the prohibitive high doses of radiation that would be necessary to obtain breast images with diagnostically useful signal-to-noise ratios and high spatial resolution. Further, the time to collect the large number of images further prohibits use of this system on patients. Conventional CT systems are therefore not suitable for use on patients for screening mammography.

What is desired then is a system for imaging a patient's breast which generates a three-dimensional image of a breast which may be used to view different levels of the breast and which uses a total radiation dose that is comparable to the dose of a standard screening mammogram. What is also desired is a system which does not require a large amount of time to collect the images necessary to generate the three-dimensional image.

SUMMARY OF THE INVENTION

In one aspect, the invention relates to a system for imaging a scene using a low dose of radiation. The imaging system includes a radiation source, a variable spatial resolution

detector, a resolution controller and an image processor. The radiation source is capable of emitting radiation toward a target scene from a plurality of angular positions, which can define, for example, an arc about the target scene In one embodiment, the radiation source is a source of x-ray radiation. In another embodiment, the radiation source moves in a series of steps of varying angular spacing along the arc to generate multiple images of the scene. The detector is positioned to detect radiation transmitted through the scene and produces radiation transmission data representing the intensity of the radiation transmitted through the scene. In one embodiment, the detector is a two-dimensional detector.

The resolution controller is in electrical communication with the detector and varies the spatial resolution of the detector in response to the angular position from which radiation is emitted by the radiation source toward the scene. The image processor receives the radiation transmission data from the detector and produces an image of the scene.

The invention also relates to a method for imaging a scene. The method includes the steps of irradiating a scene from a plurality of angular positions, detecting radiation transmitted through the scene at a plurality of different spatial resolutions, producing radiation transmission data representative of the intensity of the radiation transmitted through the scene at each of the plurality of angular positions, and producing a three-dimensional image of the scene.

In another aspect, the invention provides a system for imaging an object, which includes a movable radiation source that can direct radiation toward the object from a plurality of angular positions non-uniformly distributed about the object. The system further includes a detector movable about at least one axis so as to detect radiation transmitted through the object at each angular position of the source. The detected radiation provides radiation transmission data that an image processor can analyze to produce an image of the object. The non-uniformly distributed angular positions can define an arc about the object. Further, these angular positions can be selected to lie in a plane extending through approximately the center of the source and that of the object. Motion controllers coupled to the source and/or the detector can be utilized to move the source and/or the detector to various angular positions.

In a related aspect, the invention provides a method of an imaging an object. The method calls for irradiating the object from a plurality of non-uniformly distributed angular